## A REVIEW OF THE CRETACEOUS MAMMALIA.[1]

BY HENRY FAIRFIELD OSBORN.

In July, 1889, I received a copy of the "Discovery of the Cretaceous Mammalia"[2] by Professor O. C. Marsh, and shortly afterwards wrote to the author calling attention to all the points in which it appeared to me he was mistaken and suggested that he should revise the paper himself.

This was a year and a half ago. In the meantime the paper has been widely distributed and its facts have been accepted without question by many who have no special knowledge of the Mesozoic mammals and with considerable hesitation and criticism by those who have. I refer especially to the notices by Lydekker,[3] Lemoine,[4] Cope[5] and Dames.[6] It seems, therefore, that it is now best to carefully review, in a manner which cannot be misunderstood either by the author or by others, what appears to me to be one of the most remarkable contributions to palæontology ever published. Criticism can, of course, be based only upon the published diagnoses, descriptions and figures in comparison with our present general knowledge of these early mammals. Other evidence is promised by the author and I venture to predict that it will confirm the greater part of the conclusions reached in this review.

First as to extent and general character: the conspectus of the author impresses us that this fauna is not only highly varied but contains forms which are mostly new to science. Four orders are believed to be represented, the Allotheria, Pantotheria, Marsupialia and Insectivora. The author finds six families among the Allotheria alone, four of which are new; five new families in all. Sixteen new genera and twenty-seven new species are described. All of the types are isolated teeth, excepting those of *Camptomus*. With the exception of *Halodon*, *Cimolomys* and *Dipriodon*, only one tooth of

[1] Presented to the Society of Morphologists, Boston, Dec. 30th, 1890; to the Academy of Natural Sciences of Philadelphia, Tuesday, Jan. 20th, 1891.

[2] "The Discovery of the Cretaceous Mammalia." O. C. Marsh, American Journal of Science, Parts I. and II., July and August, 1889.

[3] Manual of Palæontology, Vol. II, p. 1268.

[4] Academy of Sciences, Paris, March 3d, 1890.

[5] American Naturalist, June, 1889, p. 490.

[6] Neues Jahrb. f. Geol. Min. u. Pal. 1890, p. 141–3.

each species is described, *i. e.* from different parts of the jaws, and we are given to understand that the associated teeth, found with each, will be described in the Memoir now in preparation by the writer under the auspices of the United States Geological Survey.

Before this varied faunal table is generally adopted into palæontological literature, let us examine the author's types and diagnoses, keeping in mind the present state of knowledge. Previous literature has apparently not been consulted by the author except in the matter of nomenclature. The result is that some well-known principles which govern the extremely complex and confusing dentition of the Multituberculates are left out of consideration entirely, as well as some of the main characters of the dentition of the Mesozoic mammals in general, and some characters which enable us to distinguish between the teeth of mammals and those of reptiles and fishes. As regards the Multituberculates (Allotheria), it is now well known that their teeth show the following characters:

1. The rows of tubercles in the true molars of one jaw fit into the longitudinal grooves of the molars of the other jaw. 2. In some families there are three rows of tubercles and two grooves in the upper molars and two rows with one groove in the lower molars (Plagiaulacidae); in other families there are conversely two rows above and three below. 3. In every known species, the last molar is invariably simpler than the penultimate molar both as to length of crown and number of tubercles. 4. That the premolars are of two types: *a.* trenchant, *b.* tubercular. When tubercular they can be distinguished from the molars by the absence of grooves, or closure of the grooves by tubercles. 5. The primary function of the incisors is to pierce the food, the secondary function is to facilitate the backward motion of the jaws as in the rodents.

As regards the ordinal terms, Allotheria and Pantotheria, they have not as yet been defined[1] or adopted. The former is equivalent to Multituberculata which has been defined and is now in general use.[2]

### *A.* Multituberculate Forms, (Allotheria.)

1. *Cimolomys gracilis*, (Pl. II, figs. 1–4), described as an upper molar; first referred to *Tritylodontidae* (Owen), subsequently to new

[1] See Osborn, "Mesozoic Mammalia," p. 257.

[2] See the works of Lydekker, Lemoine, Döderlein, Trouessart, Schlosser, Osborn and others.

family *Cimolomidae*.—Comparing this type with the upper molar of *Neoplagiaulax*,[1] Lemoine, we find it is a first upper molar of one of the *Plagiaulacidae*, Gill.

2. *Cimolomys bellus*, (no figure), the type is referred to a distinct species of *Cimolomys*.—The description and measurements indicate that it is a second upper molar of *C. gracilis*.

3. *Cimolomys digona*, (Pl. VII, figs. 1–4), the type is described as an upper molar of a third species of this genus, referred to the *Cimolomidae*.—It is an upper molar of one of the *Plagiaulacidae*.

A premolar, (Pl. VII, figs. 13–16), is rightly described as an upper premolar and correctly associated with this genus, (compare fig. 19, Lemoine[2]).

4. *Cimolodon nitidus*, (Pl. II, figs. 5–8). The type is described as an upper molar representing a new genus and family, the *Cimolodontidae*.—Comparing it with the lower molars of *Ptilodus*,[3] Cope, it is evident that the type is a first lower molar of one of the *Plagiaulacidae*.

5. *Nanomys minutus*, (Pl. II, figs. 9–12), the type is described as a last upper molar of the left side and referred to the *Cimolodontidae*.—A comparison with *Ptilodus* shows that it is a last lower molar of the right side, belonging to one of the *Plagiaulacidae*.[4]

6. *Halodon sculptus*, (Pl. III, figs. 11–13). The type is a fourth lower premolar rightly referred to one of the *Plagiaulacidae*.

A superior incisor, (Pl. III, figs. 1–3) is referred to this species.—It apparently belongs to a much larger form.

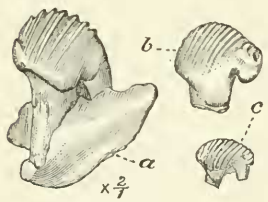


Fig. 1.

*Halodon*. Fourth inferior premolars of *a*, *H. sculptus*; *b*, *H. serratus*; *c*, *H. formosus*. After Marsh. All type specimens.

7. *Halodon serratus*, (Pl. III, figs. 14–17). The type is a fourth lower premolar, a smaller species rightly referred to one of the *Plagiaulacidae*.

A superior incisor, (Pl. III, figs. 14–17) is referred to this species.—It apparently belongs to a larger form.

It is a well known fact that the upper molars of the *Plagiaulacidae* have three

[1] "Étude sur le Neoplagiaulax de la Faune Éocène inférieure etc." Bull. d. l. Soc. Géol. de France, Feb. 12, 1883, p. 259. Pl. VI, fig. 17.

[2] Op. cit., Pl. VI, fig. 19e.

[3] This type (*C. nitidus*) has four internal and seven external tubercles; while *Ptilodus troversartianus* has four internal and six external tubercles.

[4] "The Tertiary Marsupialia," Cope, Am. Nat., July, 1884, p. 694.

rows of tubercles while the lower molars have but two, and that the cusps of the lower rows fit into the valleys of the upper teeth. This is beautifully demonstrated in the author's own figures as here reproduced and rearranged in figure 2;—*a* is the type of *Cimolomys gracilis*, which fits upon *c*, the type of *Cimolodon nitidus*; while *b*, the type of *Nanomys minutus* would probably be found to coincide similarly with the type of *Cimolomys bellus*, unfortunately not figured by the author. This gives us the characters of the molars of what was possibly a new genus (*Cimolomys*) of the *Plagiaulacidae*, intermediate between *Plagiaulax* with three well developed premolars, and *Ptilodus* with one large and one extremely small premolar. This genus cannot at present be defined, because so far as we can compare the molars and premolars, they closely resemble in size and development the corresponding teeth of *Ptilodus*. The premolars of this genus are, of course, found in the species of *Halodon*. The premolar referred to *H. serratus* agrees best in size with the molars of *C. gracilis*.

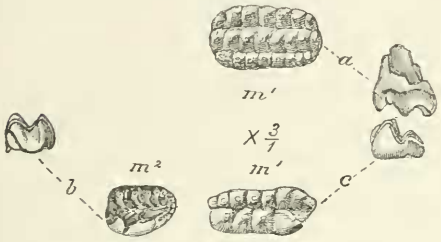


Fig. 2. *Upper and lower Molars of Cimolomys.* (Cimolomidae), *a, Cimolomys gracilis.* (Cimolodontidae), *b, Cimolodon nitidus c, Nanomys minutus.* After Marsh. All type specimens.

The accompanying restoration of the upper and lower jaws of *Cimolomys gracilis* shows the various relationships of this animal as given in the above diagnoses by the author:

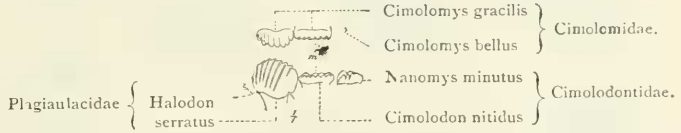


Fig. 3.
Upper and lower molars and premolars of *? Cimolomys*, in position.

These relationships will probably be increased, rather than diminished by future discoveries.[1] As it is, an upper and lower jaw referred to three families, five genera and five species is without precedent.

[1] See *Allacodon lentus* which belongs either to this genus or to *Meniscoëssus*.

8. *Dipriodon robustus*, (Pl. II, figs. 13–15). The type is probably correctly described as a last upper molar of the left side; it is referred to a new family the *Dipriodontidae*.

9. *Dipriodon lunatus*, (Pl. II, figs. 16–18). The type is rightly described as a first or second upper molar.—Keeping in mind the larger size and greater complexity of the more anterior molars, there is no ground for referring it to a new species.

10. *Tripriodon coelatus*, (Pl. II, figs. 19–21). The type is described as a first upper molar and is referred to a new family the *Tripriodontidae*.—It resembles in the arrangement of its denticles the lower molars of *Stereognathus*, and, as shown below, is a last lower molar belonging to the genus *Meniscoëssus*, Cope.

11. *Selenacodon fragilis*, (Pl. II, figs. 22–24). The type is described as an upper molar distinguished by crescentoid tubercles from the foregoing.—It is an anterior lower molar belonging to the genus *Meniscoëssus*, Cope.

Fig. 3*a*. *Meniscoëssus conquistus*, Cope. Type. An inferior molar x 2.

12. *Selenacodon brevis*, (Pl. VII, figs. 9–12). The type is described as an upper tooth apparently from the left side.—As the accompanying figures show, it agrees in every detail, except the degree of wear, with the type of *Meniscoëssus conquistus*, Cope; it is a lower molar, probably the last.

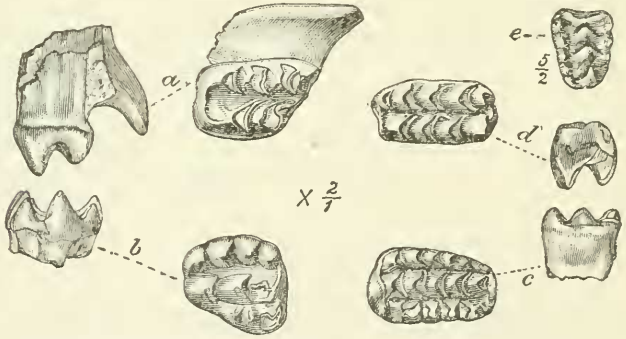


Fig. 4. *Upper and lower molars of Meniscoëssus.*

(Dipriodontidae) *a*, *Dipriodon robustus*, crown view and end view; *d*, *D. lunatus*, crown view and end view. (Tripriodontidae). *b*, *Tripriodon coelatus*, crown view and end view; *c*, *Selenacodon fragilis*, crown view and end view; *e*, *S. brevis*. After Marsh. All type specimens excepting *c*.

The lower incisor (Pl. VIII, figs. 1–3) is probably correctly referred.

13. *Tripriodon caperatus* (Pl. III, figs. 18–20). The type is correctly described as a lower incisor. No ground is assigned for referring it to a new species. Similar incisors of smaller size (Pl. III, figs. 21–22; Pl. VIII, figs. 1–3) are referred respectively to *Tripriodon coelatus* and *Selenacodon brevis*.

This collection of molars demonstrates that *Meniscoëssus*, like *Stereognathus*, belongs to a family in which the tubercles are crescentoid and arranged in two rows in the upper molars and three rows in the lower molars. This is admirably shown in the author's own figures as rearranged in figure 4. *a*, The type of *Dipriodon robustus* is seen to fit upon *b*, the type of *Tripriodon coelatus*. *d*, and *c*, belong to older individuals but the worn cusps and valleys coincide; they are respectively the author's types of *Dipriodon lunatus*, and a molar referred to *Selenacodon fragilis* as it agrees exactly with the type except in point of wear.

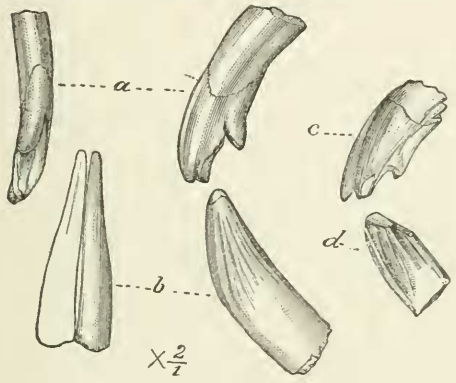


Fig. 5.

*a*, "Upper incisor of *Halodon sculptus*;" *b*, "Lower incisor of *Tripriodon caperatus*," type; *c*, "Upper incisor of *Halodon serratus*;" *d*, "Lower incisor of *Selenacodon brevis*." After Marsh.

The lower incisor, type of *Tripriodon caperatus*, corresponds in size with these molars, the two smaller incisors, referred to *T. coelatus* and *Selenacodon brevis*, have the same shape and grooved sides. (1) When these incisors are placed side by side as in figure 5 with the upper incisors referred by the author to *Halodon sculptus* and *Halodon serratus* we observe that the longitudinal and transverse diameters of the crowns and fangs coincide exactly in measurement, rendering it highly probable that they belong to the same species. (2) The question is, do these teeth belong to *Halodon* or *Meniscoëssus?* We observe that the lower incisor associated with

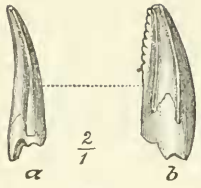


Fig. 5a.
Tooth determined as an 'upper incisor' of *Dipriodon robustus.*

*Halodon formosus* (Pl. VIII, figs. 32–35), has the enamel confined to a band as in *Ptilodus* and *Neoplagiaulax*. It is smooth. It is, therefore, probable that all these striated, completely enamelled incisors belong to *Meniscoëssus*. (3) When moreover it is seen that these incisors are far too large to be associated with the premolars of *H. sculptus* and *H. serratus*, we have further grounds for associating them with *Meniscoëssus* with which they agree in size. The tooth assigned by the author as the upper incisor of *Dipriodon robustus* apparently belongs to a reptile. It is unlike any incisor hitherto found with the Multituberculata.

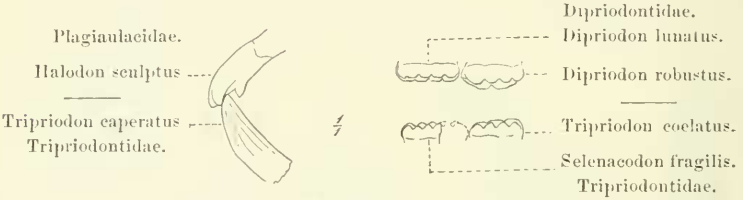


Fig. 6. Upper and lower molars of *Meniscoëssus* in position. (Association of incisors with molars conjectural.)

The accompanying restoration is based upon the foregoing considerations and shows that according to the author the relationships of *Meniscoëssus* are as varied as those of its contemporary, *Cimolomys*, including three families, four genera and seven species.

14. *Allacodon lentus* and *A. pumilus* (Pl. VIII, figs. 22–26–31). The types are described as upper molars of a genus related to *Allodon* and *Bolodon* and referred to the *Allodontidae*.—It is a universal characteristic of the molars of the Multituberculata that, as the grooves are adapted to fore and aft wear, the tubercles are arranged on the sides; in the type of *Allacodon* a tubercle stops the valley; these types are unadapted to fore and aft wear, they are, therefore, probably premolars and belong either with *Meniscoëssus* or *Cimolomys*, or possibly with some other genus, the molars of which are not represented in this collection. Upper premolars of this type are seen in *Chirox*, Cope; *Bolodon*, Owen; and *Ctenacodon*, Marsh.

15. *Oracodon anceps*, (Pl. VIII, figs. 13–16). This type is rightly described as a premolar, but no grounds are given for considering that it belongs to a distinct genus and species.

Fig. 7.
*Allacodon lentus.*
After Marsh. Types.

16. *Camptomus amplus*, (Pl. V, figs. 1–2). The type is a scapula with which are associated other bones, calcaneum, astragalus, interclavicle. No grounds are assigned for separating these remains from genera founded upon the teeth.—The astragalus bears the same proportion to the molar-teeth of *Meniscoëssus* that we observe in *Polymastodon;* it is also apparently perforated. The affinities of these forms to the Monotremata have been observed by Cope; the coraco-scapular facet, therefore, strengthens the supposition that some of these bones at least, belong to *Meniscoëssus*. In any case they cannot be considered as good types.

This completes the Multituberculate forms.

### *B.* Trituberculate Forms.

17. *Dryolestes tenax*, (no figure). The type is a lower jaw with a mylohyoid groove, in which the number and character of the teeth "cannot be determined." The author's reference is provisional.

18. *Didelphops* (*Didelphodon*) *vorax*, (Pl. IV, figs. 1–3). The type is an upper molar, distinguished from *Didelphys* by intermediate tubercles.—This character does not separate it from the large number of trituberculates with similar molars; the genus is, therefore, undefined at present. The other species *D. ferox* and *D. comptus* are also undefinable.

19. *Pediomys elegans*, (Pl. IV, figs. 23–25). The type is an upper molar.—It is not distinguished generically from *Didelphodon*.

20. *Cimolestes curtus* and *incisus*, (Pl. IV, figs. 8–18). The types are lower molars.—Like *Didelphodon*, these forms cannot be defined, they are tuberculo-sectorial.

It is evident that we have here remains of two distinct and probably new genera which may be accepted without definition.

### *C.* Incertae sedis.

21. *Stagodon nitor*, (Pl. VII, figs. 22–25). The types are a few teeth with single fangs, referred to a new family the *Stagodontidae*. —They do not resemble the teeth of any known mammal although described as having two fangs, which are, however, not shown in the figures. The premolar associated is distinctly mammalian.

22. *Platacodon nanus*, (Pl. VIII, figs. 4–12). The types are compared to the molars of *Chrysochloris*.—They do not bear the most remote resemblance to the molars of *Chrysochloris* or any other known mammal. Prof. Dames considers that they belong to the Cyprinoid fishes.[1]

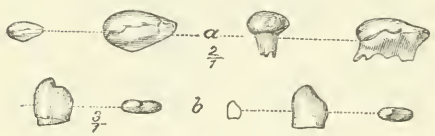


Fig. 8.
(Stagodontidae), *a*, *Stagodon nitor*. After Marsh. Types.
*b*, *Platacodon nanus*. After Marsh. Types.

The above types do not resemble in the most remote degree the molars in either the multituberculate or tritubercular series—the only two mammalian series hitherto represented in all the discoveries of Mesozoic or Eocene times. Nor have they, as figured, any of the characteristics which we expect to find in mammalian teeth.[2] They should, therefore, be considered either as reptilian or ichthyopsidan; we cannot agree with the author that they are "evidently mammalian."

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The above analysis may be summarized under the following heads, we find that the author has: 1. Separated parts which evidently belong together, *vide*, various teeth of *Cimolomys* and *Meniscoëssus;* 2. United parts which apparently or certainly do not belong together, *vide*, the large upper incisors with *Cimolomys*, the reptilian or fish molar of *Stagodon* with a mammalian premolar, the reptilian tooth as an upper incisor of *Dipriodon;* 3. Associated or identified reptilian or ichthyopsidan teeth as mammalian, *vide*, *Platacodon*, *Stagodon* and incisor of *D. robustus*.

The large Cretaceous fauna described by the writer is therefore seen to be principally composed of synonyms. We must eliminate:

1. The terms preoccupied by other authors.
2. The terms founded upon different parts of the same animals and thus largely preoccupied by the author himself.
3. The terms founded upon imperfect or indefinite types.
4. The terms founded upon reptilian or ichthyopsidan teeth.

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[1] This author reaches conclusions very similar to mine in regard to this paper. Neues Jahr. Min. Geol., 1890, pp. 141–143.

[2] See H. G. Seeley, "On the Nature and Limits of Reptilian Character in Mammalian Teeth." Proc. Roy. Soc., April 4, 1888, p. 129.

| | | |
|---|---|---|
| A. Allotheria. | = | A. Multituberculata, Cope. |
| 1. *Cimolomidae.* | | |
| Cimolomys gracilis | | |
| " bellus | | |
| " digona | | |
| 2. *Cimolodontidae.* | | |
| Cimolodon nitidus | = | 1. *Plagiaulacidae* Gill. |
| Nanomys minutus. | | *Cimolomys*, Marsh, two or three species. |
| 3. *Plagiaulacidae.* | | |
| Halodon sculptus | | |
| " serratus | | |
| " formosus | | |
| 4. *Dipriodontidae.* | | |
| Dipriodon robustus | | |
| " lunatus | | |
| 5. *Tripriodontidae.* | = | ? 2. *Stereognathidae*, fam. nov. |
| Tripriodon coelatus | | *Meniscoëssus*, Cope, two species. |
| " caperatus | | |
| Selenacodon fragilis | | |
| " brevis | | |
| 6. *Allodontidae.* | | |
| Allacodon lentus | | Probably preoccupied. |
| " pumilus | | |
| ? Camptomus amplus | | Indefinite types or preoccupied. |
| ? Oracodon anceps | | |
| ? B. Pantotheria. | | Indefinite type. |
| ? 7. *Dryolestidae.* | | |
| ? Dryolestes tenax | | |
| C. Marsupialia. | | B. Order indeterminate=Creodonta, Insectivora or Marsupialia. |
| Didelphops vorax | = | *Didelphops*, Marsh, two species. |
| " ferox | | |
| " comptus | | |
| Cimolestes incisus | = | *Cimolestes*, Marsh, ? species. |
| " curtus | | |
| D. Insectivora. | | Not defined. |
| Pediomys elegans | | |
| E. Incertae sedis. | | |
| 8. *Stagodontidae.* | | Founded upon Reptilian or Ichthyopsidan teeth. |
| Stagodon nitor | | |
| Platacodon nanus | | |

This reduces the Cretaceous mammals described in these two papers to one well determined order or sub-order, two well determined families and four or five genera, one of which can now be well defined (*Meniscoëssus*) while the remainder are probably distinct genera which we may be able to define by the acquisition of more material (*Cimolomys*, *Didelphops* and *Cimolestes*). There is no question that the majority of the remaining generic names are synonyms although it is quite possible that some of the types described, such as *Oracodon* and *Pediomys* may be found to represent distinct or new genera.

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It may be said that this analysis has almost entirely eliminated the work of the author. This unfortunately is what is necessary if we would render this contribution of any permanent value in palaeontology. We are then left with a series of teeth which represent rare skill on the part of the collector and are figured with remarkable accuracy by the draughtsman. A few points of interest upon the collection as a whole may be mentioned.

The *Multituberculata*. The preponderance of teeth belonging to members of this order would appear to indicate that it flourished during this period. *Cimolomys* represents a connecting form between *Plagiaulax*, upper Jurassic, with three premolars and *Ptilodus* of the lowest Eocene with two. The smallest species, *C. formosus*, apparently has as many grooves upon the fourth premolar as we observe in *Ptilodus*, and the first lower molar has even more tubercles than we find in the corresponding tooth of the lower Eocene genus. These grooves and tubercles mark the stages of development, and it would appear that *Cimolomys* is not far removed from *Ptilodus*; this relation can only be determined by the discovery of additional teeth, we may find that *Cimolomys* has a large third premolar.

Another interesting fact is that *Meniscoëssus* does not belong with the *Plagiaulacidae*, as has been generally supposed hitherto,[1] but should apparently be placed with *Stereognathus* (with which its resemblance in molar structure has always been recognized) in a distinct family, the *Stereognathidae*, distinguished by the presence of two rows of tubercles in the upper molars and three in the lower, of crescentoid pattern. The more numerous tubercles in *Meniscoëssus* would accord well with its more recent character.

[1] Cope, Osborn, Lydekker.

There are thus apparently only two families of the multituberculates represented here unless as the author has suggested, *Allacodon* belongs to the *Bolodontidae*. We have yet to find the successors of the *Tritylodontidae* and predecessors of *Polymastodon* and *Chirox* of the lower Eocene.[1]

As for the tritubercular forms there are evidently two distinct genera which probably belong to different families. The types of *Didelphops* and *Cimolestes* closely resemble molars found respectively among the Mesodonta, the Creodonta, Insectivora and Marsupialia. Their systematic position is, therefore, very uncertain from this evidence. They mark, however, a very great advance upon the Jurassic forms in tooth evolution. We find in *Didelphops*, the earliest low-crowned tritubercular molar which has been obtained, with one or two intermediate tubercles, while the lower molar is the earliest quinquetubercular tooth known. The *Cimolestes* molar is tuberculo-sectorial and presents a less marked advance upon jurassic tooth types, but has nevertheless a broad talon, with both the entoconid and hypoconid developed, whereas all jurassic forms present the hypoconid only.

The bones of the appendicular skeleton present a number of very interesting points, some of which the author mentions; these are, the coracoid facet upon the scapula; the interclavicular. We note also the flat astragalus, without a neck, apparently perforated by an astragalar foramen,[2] and with a broad cuboidal facet as well as the navicular facet. The calcaneum has a narrow sustentaculum.

We look forward with great interest to Part III of this series of papers, as the collection is a most valuable and interesting one, and the above review is not intended in any way to depreciate the importance of an increased knowledge of the Cretaceous mammals.

[1] The nearest resemblance to *Polymastodon* is that observed in the striated lower incisors here copied in figure 5. This genus will undoubtedly be found represented in these beds.

[2] The observation rests solely upon the figure. All astragali of the lower Eocene display this foramen.